Teaching Science Through Multimedia: Transitioning from a Technology-Centered Approach to a Learner-Centered Approach

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Teaching Science Through Multimedia: Transitioning from a Technology-Centered Approach to a Learner-Centered Approach

by

Daniel Roberti

A project submitted to the Department of Education and Human Development of the State University of New York College at Brockport in partial fulfillment of the requirements for the degree of Master of science in Education

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Chapter I - Introduction

Digital video content has become increasingly popular and accessible among the population as a means of not only providing entertainment, but for consuming new information as well. Learning a new skill or subject can now be accomplished easily via online tutorials and educational videos without ever needing to step into a classroom or sit through a live lecture. Starting in the early 2000’s, several educators started to realize this and the potential of using online multimedia as a way to deliver content to their students. Their idea being that students could watch the lecture and take notes outside of the classroom, while experiencing more problem-based in-class activities. The intent of early adopters of the flipped classroom, as this learning environment was soon deemed, was to switch the focus of the classroom from a teacher-centered lecture to a more student-centered one. In making this switch, students are able to receive more one-on-one feedback and assistance from the teacher and their peers in a more meaningful and personalized fashion. With more and more students gaining access to the internet at home and outside of the classroom, many teachers have had little concern when it comes to assigning videos for their students to watch outside of class.

While the relatively new concept of the flipped classroom is highly dependent and bolstered with the rise of educational video content, the use of video as a supplement to traditional lesson plans in the classroom is not a new concept by any means. Showing videos in moderation can provide engagement for students because the teacher is able to expose the class to phenomena that they could not normally be exposed to in the typical classroom. Videos displaying phenomena at the molecular level, such as ribosomal translation, can be demonstrated with considerably more clarity than static images on a presentation slide or poster. Video
animations can also be beneficial to English Language Learners or other students that may have difficulties reading and comprehending the textbook or written notes.

An issue with traditional in-person lecture as a way of transmitting information to students is that not all students can learn and comprehend the content of the lesson at the same pace. It is highly likely that throughout a class-long lecture, at least some of the students can become distracted or simply not understand the material at one or more points during the class. These missed pieces of information can accumulate over time and by the end of a unit, the students that were not able to keep up with the pace of the lectured material will have serious gaps in understanding which will inevitably carry over into future topics as well. However, when students are provided with videos to watch in and out of class that reinforce what is being taught, they are able to re-watch the videos at their convenience to learn the content at their own pace. Given this ability to learn at a pace more suitable to them, the accumulation of gaps in knowledge can be mitigated and the students can review material as needed and as many times as they desire.

Learning science through video as opposed to lecture has several benefits, which will be discussed further in the following chapter, however, the primary concern that many critics of the flipped classroom have expressed does not regard the act of flipping, but the videos themselves. Unfortunately, not every video that is intended to be educational is geared to be used as an appropriate educational resource. Even if the intent of the video’s creator is to teach, this does not entitle the video to be an ideal supplement or replacement to a traditional lecture. There are several criteria that an educational video must meet in order for it to be highly effective for students to not only learn, but retain and comprehend the information. These criteria ensure that each video: addresses misconceptions, does not over-simplify explanations, is an appropriate
length, and includes some sort of interactivity. This final criterion, interactivity, will be the main focus of this project. Non-interactivity among digital media is the primary issue with video learning that cannot be addressed by modifying or altering the actual footage or format of the video. It is widely agreed upon by educators that active learning is much more effective when compared to passive learning. For this reason, video learning needs to be converted to an active state, rather than a passive one. Watching and listening as the animations move across the screen is not enough to incentivize the full attention of the student. Using a program to pause the video periodically and ask the viewer questions to ensure he or she is meeting the learning targets of the video is imperative to both the student and the teacher. In this project, the Edpuzzle software is explored and utilized to implement questions into effective educational videos.

As stated previously, video content alone is not enough to teach students in both traditional and flipped classroom environments. With Edpuzzle, videos are assigned for students to watch via the Edpuzzle website, where they can be cropped and questions can be embedded into them as well. From the students’ end, it is the same experience as watching a video that can be found on YouTube with periodic breaks programmed in to assess their understanding. These pauses can ensure the students are focused on the video itself and not just letting it play in the background or in another tab while are more consumed with other activities. From the teacher’s end, they can see how long each student took to complete the assignment, how much of the video was watched, and which questions were missed most frequently. By identifying the characteristics of effective video content and incorporating Edpuzzle into a traditional or typical flipped classroom, the concerns of most critics of video learning are removed and this normally passive learning style becomes much more interactive and engaging for the students.
Chapter II - Review of the Literature

Effectiveness of technology, multimedia, and the flipped classroom method

The flipped classroom is used by many educators for a variety of reasons. For one, it allows more differentiation of instruction. Since the “lectured” material is saved for students to interact with at home or outside the classroom, this enables teachers to differentiate the content for individual students much more efficiently. Differentiation is especially important at the middle school level because learning differences at this age group are the most profound (Winter, 2018). Self-motivation has also shown to be improved in classrooms where differentiated instruction has been implemented. In class activities can also be differentiated based on a variety of factors because students are learning in smaller groups rather than all together as a single entity listening to a lecture. This method is appealing to many because it is a blend between student-centered constructivism as well as direct instruction. This blend results in the integration of two learning diverse learning spaces provided to students, an individual learning space with instructional content and a group learning space that involves student learning through collaboration. Despite its rise in popularity in the world of education, the flipped classroom has seen much criticism at the K-12 level due to the fact that the majority of the research associated with it focuses primarily on the postsecondary setting. This leaves the K-12 teachers with little published evidence to support their switch to developing a flipped classroom.

This study looks at the effect the flipped classroom has on academic performance and motivation on middle school students. A social studies class of 35 sixth grade students participated in the study, which lasted eight weeks in length. Students that participated were immersed into a flipped classroom that used a dual learning space design. This means that
instructional content was delivered to students in the form of multimedia (this is known as the Individual Space) and a variety of activities were done in class (this is known as the Group Space). The Group Space activities were set up as stations and had differentiated group and individual requirements of students. Students were surveyed at the end of the unit on several aspects of their experiences in the flipped classroom environment such as ease of access to online assignments, perceived learning, and effort put forth. Students’ overall grades were collected as well and performance groups were established.

After analyzing the results of the surveys and performance observations, findings show that the flipped classroom structure was particularly effective in encouraging average performing students to put forth a high degree of effort. This was most likely due to the use of differentiated learning activities within the Group Space. Results also conclude that flipped learning increases student motivation when combined with differentiated activities. While not mentioned in the paper, these results reveal that a flipped classroom environment combined with a response-to-intervention model may be a highly effective practice at the middle school level for improving both student motivation as well as performance (Winter, 2018).

The continuous improvement and availability of technology in recent years has allowed schools around the world to adapt atypical learning environments such as the flipped classroom (Sezer, 2017). The flipped classroom is designed so that students learn the material at home via a technological medium such as an asynchronous PowerPoint presentation and they practice the material learned the night before in the classroom the following day. The initial road block that most flipped classrooms ran into was that some students did not have access to technology outside of the classroom environment. However, with availability of one-to-one technology programs becoming more common in schools, flipped classrooms now have the resources they
need to thrive and succeed in schools of all socioeconomic tiers. The primary focus of this study was to determine the effect of a flipped classroom enhanced with technology on the achievement and motivation of students. The three research questions were: (1) Is there a significant difference in the academic achievement levels of sixth-grade students taught in a flipped classroom environment in comparison with students taught with traditional methods? (2) Is there a significant difference between the motivation levels of sixth-grade students taught in a flipped classroom environment and those of students taught with traditional methods? And (3) what are the opinions and thoughts of sixth graders taught in a flipped classroom environment?

The research questions were answered using a mixed research design of both quantitative and qualitative data. Two groups of sixth graders from the same school were selected to be part of the study. The control group had 33 students who were taught using the typical classroom teaching methods and the experimental group had 35 students who were taught using a flipped classroom approach over the course of two weeks. To measure the difference in academic achievement among the students in both groups, a pretest and posttest were given to all students in the study. The pretest and posttest were identical 23-item multiple choice questions. Another 23-item test was distributed to determine the motivation levels of the students before and after the trial period. Finally, students that were part of the experimental group were interviewed with open-ended questions. When comparing the pretest and posttest scores between the experimental and control groups, it was found that the flipped classroom method had a large effect on students’ academic achievement levels. The students in the flipped classroom method improved their scores from the pretest to the posttest by around 21% whereas students in the traditionally taught method saw their scores improve by around 13% from the pretest to posttest. As for motivation variables between the groups of students, the results from the test show that the
students in the experimental group had higher levels of motivation following the trial period when compared to their colleagues taught in the traditional setting. During interviews with students in the experimental group, several students expressed their positive perception of the flipped classroom. Several of the students said that this method allowed them to ask their teachers more questions during class time. Students in the flipped classroom also had a more positive perception on homework and taking responsibility for their own learning.

The model of the flipped classroom, similar to other student-centered instructional models, is based on the constructivist theory of learning. The constructivist theory is based loosely on the Zone of Proximal Development in that it emphasizes socially constructing meaning from newly acquired information rather than constructing it individually. By delivering information outside of the classroom, more face-to-face time between students and teachers with students can be allotted, which allows teachers to have more one-on-one contact with every student each day (Olakanmi, 2017). The flipped classroom also encourages the teaching of 21st century skills, which include collaboration, self-direction, and critical thinking. Other case studies throughout the literature show that there is research both supporting, as well as criticizing, the model of the flipped classroom in regard to its ability to positively impact students’ conceptual understanding of content. Despite the criticism it has received, current research supporting both sides of the debate have concluded that students prefer to learn collaboratively. While the ideal model of the flipped classroom may not exist just yet, it is an exceptional method that can be used to promote collaboration among students. Other current studies have shown that learning content through video or other forms of multimedia are favored by students because they can pause, rewind, or go back and re-watch any lecture they choose if they feel they need to review a certain topic. It has also been shown that students in a flipped
classroom feel more empowered to use technology to find information on their own when compared to students taught in a traditional setting.

This study looked at the effects of a flipped classroom model on students’ attitude towards chemistry and overall performance. It aimed to answer the following questions: (1) what are the effects of the flipped classroom on senior secondary school chemistry students’ performance in rate of chemical reaction as measured by the RRKT (rates of reaction knowledge test)? (2) What effects does a flipped classroom environment have on students’ attitudes towards learning chemistry as measured by the CAS (chemistry attitude scale)? And (3) what are the benefits and challenges of using a flipped classroom model to teach and learn chemistry?

Over the course of a three-week period, 66 chemistry students took part in one of two classroom environments teaching rates of reactions. These students were randomly selected to be part of either the control group (a traditional classroom setting) or the experimental group (a flipped classroom setting). The flipped classroom model used in this experiment was a standard model and involved students watching an assigned video for homework and completing inquiry-based activities in class with peers facilitated by the teacher. Students were given an identical pretest and posttest in both groups. They were also surveyed after the intervention had ended to determine the students’ attitude towards learning chemistry. Prior to the intervention, both groups of students had no significant differences in academic performance or attitude towards chemistry. Quantitative results show that students in the experimental group had a significantly higher gain in score on the posttest compared to the pretest, revealing that students in the flipped classroom method had achieved a higher level of understanding of the content. Results from the CAS survey also showed that the mean gain in attitude towards learning chemistry was significantly higher than the mean gain for students that were taught in the traditional classroom.
Students that were part of the experimental group were interviewed on their feelings towards the concept of the flipped classroom. Researchers found that 85% of students talked about an increase in their participation in class, showing that the flipped classroom had a positive impact on student involvement in the classroom. One of the most common things students talked about in the interviews was that they appreciated the fact that they could learn each topic at their own pace. If they didn’t fully understand something after learning it the first time, they had the ability to go back and re-watch the lecture provided to them at any time. Implication in this study show that the qualitative data collected during the interviews is just as, if not more, revealing as to how much of a positive impact the flipped classroom model can have on the students within it. This method is especially effective for STEM related classes because these courses contain a plethora of content knowledge that may be abstract to students learning it for the first time. The fact that the flipped classroom method allows students to be retaught topics on demand can drastically improve their chances of succeeding thus improving their motivation and attitude toward other STEM based classes.

As many flipped classroom researchers have concluded, the benefits of the flipping one’s classroom are numerous and the majority note that these benefits include students being able to move at their own pace, teachers having more one-on-one time with students, students experiencing increased levels of student achievement and engagement, among others (Unal, 2017). The research described in the present study examines a total of 16 teachers that teach grade levels 4 through 10. They also taught core subjects such as mathematics, science, social studies, and language arts. The abundance of teachers participating in this study allowed for researchers to also study the teachers’ perception of the flipped classroom as well as their overall satisfaction with this teaching method. The teachers each prepared 5-day flipped lessons for two
groups of students, one group was taught using traditional methods while the other group of students was taught using the flipped classroom method. A pretest was distributed to the students prior to the start of the intervention. At the end of the intervention, students took an identical posttest to measure their average gain in performance. Finally, students and teachers took a post-intervention survey asking them on their perceptions of the flipped classroom. The model of the flipped classroom used in this study was three-phase model which included pre-class, in-class, and after-class activities. The pre-class and in-class activities are typical of a standard flipped classroom, however, the after-class activities in this model included self-evaluation and reflection which are not part of the standard model. The pre-class portion included 15-25-minute video lessons created by the teachers that the students were required to watch prior to coming to class. The in-class activities included individual practices, student presentations, and quizzes which differs from other standard flipped models because they are typically more oriented towards allowing students to work collaboratively.

The results from the pretest and posttest indicate that the majority of classes that utilized the flipped classroom method had significantly higher scores than their counterparts using a traditional teaching method. Ten of the 16 teachers saw these statistically significant results. Five of them still saw improved higher mean gains in the flipped classroom, albeit the improvements were not statistically significant. Only one of the teachers found that the traditionally taught class had significantly higher scores than the flipped class. When analyzing the qualitative data collected from the student surveys, 94% of the students in the flipped classroom environments stated that the new learning format was successful for them. A majority of these students (88.46%) also claimed that the flipped classroom method allowed them to learn at their own pace. Interestingly, while the videos that the students were required to watch before coming to
class were available to watch on mobile devices, only 2% of students said they watched them on their mobile devices, however, 73% said that they watched the videos on a computer (either desktop or laptop). As for the teachers’ survey results, 15 of the 16 participating teachers found that their students learned better and scored higher on assessments. Furthermore, 81% of respondents said that the flipped classroom provided them with a better opportunity to interact with students.

One of the major challenges that teachers faced with the flipped teaching method was that they found it took much more effort to prepare and was very time consuming. While there is much work to do at the beginning of a flipped classroom format, following cycles should theoretically take less time because the lectures have already been produced. Secondly, teachers stated it was challenging to know for sure that their students had fully watched the videos before coming to class. With new programs such as Edpuzzle that can track how much time a student spends watching and re-watching videos, this challenge should become less common as these programs become more prevalent in the classroom. Overall, the benefits to the flipped classroom, even at the K-12 level, have shown to outweigh the challenges in several aspects and studies.

Cognitive theory of multimedia learning

The term *Cognitive Theory of Multimedia* was coined by Richard E. Mayer. According to Mayer (2009), a cognitive theory of multimedia learning assumes that information processing is carried in two channels - one for visual/pictorial, and one for auditory/verbal processing. It also assumes that each channel has limited processing capacity and that active learning entails carrying out appropriate cognitive processing during learning.
Mayer states that there are two approaches to multimedia design - a technology centered approach and a learner-centered approach. The former is the approach most typically seen in traditional multimedia design and is identified as being focused more so on the promotion of the technology. The issue with this approach, as Mayer puts it, is that humans are forced to adapt to the demands of the technology rather than the there being an interest in promoting human cognition. Furthermore, in a learner-centered approach, the design begins with an understanding of how humans learn and how the brain processes information. Based on the learner-centered approach, multimedia should be used to aid human cognition by promoting active, rather than passive learning.

Active learning involves more than simply listening and watching a digital video. In order for learning to be considered active, the learner must be involved in three actions: selecting, organizing, and integrating. Selecting meaning making connections both within the video and between the video and the learner’s outside knowledge. This can be done by answering questions about the material previewed in a video, for example. When a learner organizes material, they are building relationships and connections among terms and words, such as identifying cause-and-effect relationships. Finally, integrating information means to make external connections between prior knowledge and the content included in the multimedia. In science studies specifically, this can be done through the refutation of certain preconceived alternate conceptions that a student might possess, although this process may differ for other content areas.

Based on Mayer’s cognitive theory of multimedia learning, the five steps in achieving successful learning through multimedia are selecting relevant words, selecting relevant images, organizing selected words into a visual mental model, organizing selected images into a visual
mental model, and lastly, integrating verbal and visual representations. When selecting relevant words and images, it is imperative to remember that a cognitive input limit exists within each learner. This implies that the words transmitted auditorily in the video must match the animations that are occurring simultaneously. Next, the order in which information arises in linear multimedia, such as a video, must allow for cognitive processing to make connections between ideas. Lastly, prior knowledge must be activated during information processing in order for the short-term memories relayed from the multimedia to become connected with previous experiences and thus become embedded in the learner’s long-term memory.

When it comes to teaching science specifically, a learner’s prior knowledge may be filled with alternate conceptions that they believe are true, albeit defy scientific facts and principles. For this reason, it is believed that activating prior knowledge in science-based multimedia by refuting common misconceptions among students.

*Teaching through misconceptions and refutations*

When learning a new concept, especially in science, students’ preexisting conceptions, whether they are in line with what is believed to be scientifically true or not, can often play large role in the amount that each student learns as well as their engagement with the material (Muller, 2008). Other research has shown that adding misconceptions to multimedia learning tools such as videos or simulations can either help or hinder learning, as they have the potential to add extraneous cognitive load on the learner which can inhibit him or her from building a coherent mental model. On the other hand, adding this extra cognitive load through the addition of discussions on misconceptions can also help students by revealing the possible differences between scientific theories and their own prior knowledge. The debate between teaching through
concise, coherent tactics as opposed to revealing alternate conceptions is ongoing. Educators that support providing their students with concise information argue that non-essential material often distracts learners and that the goal of instruction should be to minimize extraneous cognitive load and maximize the germane load.

To examine the effects of teaching through both coherence as well as with revealing misconceptions, a relatively large study was conducted with 678 first-year physics students. The students were taught a lesson on Newton’s First and Second Laws of motion. The students were broken up into four experimental groups and each group was taught the lesson using a different teaching method, all of which were based on an online video. The first group was provided with a 7-minute expository video that did not address any common student misconceptions. The second group was treated with an extended expository video (~11 minutes in length) which added extra interesting information that was not assessed on the pre- or posttest. This also did not include addressing misconceptions. The third group was treated with the same expository video as the first group, but with an added refutation segment at the beginning of the video (total video length was 9.5 minutes). The refutation segment specifically addressed several common misconceptions that students have on the Laws of motion. The final group was treated with a video (~11 minutes) that included a simulated conversation between a student and a tutor where the student’s misconceptions were revealed. The same misconceptions from the refutation video were also addressed in the dialogue.

Identical pretests and posttests were given to all students and their gains in scores were measured. The mean gain scores for the refutation and dialogue methods were significantly greater than those from the exposition and extended exposition. This shows that students that were exposed to the methods addressing misconceptions achieved much higher gains when
compared to the students that were provided with just the coherent video lessons. Implications of this study reveal that additional information in the form of addressing misconceptions does not interfere with student learning and in fact, can promote a higher level of understanding of scientific concepts. In a flipped classroom environment where students are given the opportunity to learn from home via multimedia sources, being sure to address common misconceptions within that multimedia is highly imperative to student content mastery.

When students are highly confident in the information, they believe to be true, being exposed to information that reveals their own misconceptions may not register with them and they may not even realize that the information they are being exposed to is contradictory to what they think is fact. Self-regulated learning can be a challenge for students, and when monitoring novel information is inaccurate, learning may not actually occur for some students. When alternate conceptions are revealed through refutation, hypercorrection of misconceptions can occur. Refutation texts can be used to hypercorrect student misconceptions and always contain two components in addition to the standard text. These components are the statement of the misconception and the explicit refutation of the misconception.

In an experiment carried out with 114 eighth-grade students, refutation texts were used to determine whether or not they enhanced the correction of high-confidence misconceptions (Van Loon, 2015). Each student was assigned randomly one of two texts. One of these texts was a refutation text while the other was considered a standard text. Each student was given a pre-reading assessment as well as a posttest which was given one week after the reading which allowed to researchers to also measure the level of retention among students. Results from the study partially confirm the hypothesis that the benefit of reading the refutation texts was significant for correcting misconceptions. The results only partially confirm the hypothesis
because the posttest scores show that misconceptions were proven to be outdated with the true/false portion of the test, however, on the extended response portion, these benefits were not shown to be significant; meaning that misconceptions can be outdated using refutation texts, yet not updated with the correct information.

Implications for this study reveal that while the refutation texts can benefit students when the goal is to update their misconceptions, the texts do not provide support for showing that they can also update the students with the correct, updated conception. Further interventions could be needed in order to fully update and update common students’ misconceptions that are associated with high confidence. One finding from Muller’s research (2008) was that some students actually found support for their alternative conceptions in refutation texts when the refutation was not direct enough or when students lacked necessary reading strategies. This is highly concerning that some refutation texts can bolster the exact conceptions they are trying to replace. In this case, it should be ensured that the refutation texts are of the appropriate reading level for their target audience and should clear enough so that students can recognize the claim that is being refuted.

In the research discussed previously, the effects of refutation texts were evaluated on the hypercorrection of student misconceptions. It was found that they are effective in outdating misconceptions, however, for some students, this is still not enough to completely incorporate this new conception into their prior knowledge. This can happen when the student does not have the correct reading strategies to fully comprehend the text. However, it has been shown throughout the literature that students learn better from text and pictures rather than text alone. This is known as the multimedia principle. Other current research shows that reading refutation texts as opposed to standard texts can improve learners’ metacognition; this could possibly be
one of the reasons why it is particularly beneficial for hypercorrecting misconceptions over standard texts alone. The effectiveness of incorporating graphics into instructional texts has also been studied heavily and results consistently show that pictures can contribute to a greater understanding of certain scientific concepts when in conjunction with relevant text.

In an experiment carried out by Mason et al (2017), the effects of using refutation graphics in tandem with refutation text was determined. The experiment took place over the course of three sessions: the pretest, the presentation of the text, and the posttest. Students received one of four texts. One of which was a standard text with a standard graphic, the second was standard text with refutation graphic, the third was refutation text with standard graphic, and the fourth was a refutation text with refutation graphic. Students were given an immediate posttest thereafter and a delayed posttest to measure the retention of content learned. Posttest analysis shows that the students that received the refutation text with the standard graphic actually had the highest posttest gains as well as the lowest rate of misconceptions among participants after the delayed the posttest. The students that read the refutation text with the refuting graphic had the second-best results, followed by the standard text with standard graphic and the group that read the standard text with refuting graphic performing the worst of the four with the highest rate of misconceptions as well as lowest delayed posttest scores. In a second study, the results revealed that readers of the refutation text, regardless of the type of graphic, showed a higher level of metacognitive awareness when compared to the readers of the standard text.

The results from these studies imply that the type of graphic does not make as much of an impact on academic achievement nor retention of misconceptions as the type of text. As long as students were reading a refutative text, the form of graphic did not make a significant difference.
The major difference was between groups that read the refutation as opposed to the standard text. There was a marginal difference in delayed retention between students that read the refutation text with the standard graphic and the refutation text with the refutation graphic where the former group performed at a higher level. This could mean that the text can help students realize where their misconceptions may be, and a more concise and coherent graphic can be more beneficial for helping students retain this novel information.

*Optimizing effective video length for students*

One factor that is often overlooked when creating multimedia content designed for children and young adults is identifying the appropriate length of an educational video. With the increasing popularity of the flipped classroom, it is becoming more and more likely that students will be required to watch more than one video assigned by multiple teachers. Due to the cognitive theory of multimedia learning as well as cognitive load theory, learners are limited by the amount of information given to them in a certain span of time. This causes implications on the appropriate length which video content creators should abide by. These cognitive limitations are especially true for younger students in middle level science classes.

A study done by Slemmons et al (2018) attempted to establish an appropriate video length for middle level students. The study took place within a flipped classroom environment where computer-based instruction took place outside of the classroom and group learning took place during the school day. Participating students were in grades 7-9 science classes. They were split up into two groups with each group alternating between short (averaged 5.52 min) and long videos (averaged 11.03 min). Students were given a pretest prior to starting the unit, a quiz after watching the video, and a summative unit assessment.
Results from the experiment showed that scores on the quizzes and summative unit assessments were higher when students watched the shorter videos, however, these scores were not significantly higher. Shorter videos had the most substantial impact on students with IEPs/504 plans. These students had higher scores on the unit test that were statistically significant. As for the self-reported survey questions following the experiment, it was determined that students perceived higher abilities to retain information following shorter videos as opposed to longer ones. They also reported having a heightened ability to focused while watching the shorter videos. While increasing video length from ~5 to ~10 minutes may not have a substantial effect on the majority of students, it does affect students that may have impaired maximum cognitive processing loads such as some student with IEPs and 504 plans. If video content creators are to produce videos for the inclusive science classroom, keeping videos shorter as opposed to lengthened may be the optimal solution.

Incorporating meaningful and engaging content in videos

In the flipped classroom and other forms of education where the majority of the learning is done at home or on the student’s own time, it is important to understand what types of learning material are best to use for students. Previous research has shown that the coherence of educational multimedia is highly sought after and has shown the best results under controlled conditions. The coherence principle states that students learn better when extraneous material is excluded because it competes for cognitive resources and can divert attention away from the important material. Information not needed or required in an instructional video and is considered more interesting is called “seductive detail.”
While the coherence principle has received plenty of empirical support in laboratory settings in the literature, there has been little research to determine the effectiveness of the coherence principle in an authentic learning environment. Muller explains that while viewing online multimedia at home, learners are under no obligation to pay attention to the instruction and would therefore benefit students in real learning settings. The purpose of this study was to study and compare the effectiveness of both coherent versus interesting instructional online multimedia on achievement and retention of material.

This study was done with students that varied in age and prior knowledge. In total, 104 students in grades 10, 11, and first year college students participated voluntarily in the study. They came from three different schools. These students were placed in two groups, one being the control group, where students would need to learn the material via an online video that was coherent and did not contain any information that was not needed for the assessment, and the other group was the experimental group, where students watched the same video, however, it contained an extra three minutes of footage that contained extra interesting content that was not required to know for the assessment. The post-test given to students consisted of multiple choice and short answer questions. After analyzing the results, researchers found that there was no significant difference between test-scores of the two groups. This is contradictory to the coherence principle because according to previous research, the students that watched the more concise video should have scored higher on the post-test at a statistically significant level.

Based on the results and findings, the coherence principle may not be applicable in an authentic learning environment. However, the hindering effects of increasing the cognitive load on students with the extra interesting, yet unimportant information may have been mitigated by the increased interest in students. In other words, even though adding extra information to the
video can increase the cognitive load on the student, it can also achieve a higher attention rate in the student and so these effects essentially cancel each other out. In this experiment, the researchers added approximately 50% more time to the video and the experiment only studied the effects of one lesson in this manner. I think that capturing the interest of the potential learner is imperative, especially if they are being told to watch the video. The student needs a reason to pay attention the video, otherwise they could just have the video playing while completely unengaged with it. That being said, I think the videos used for purely educational purposes should be both coherent and entertaining by making them concise and adding just the right amount of interesting properties to them without adding too much time to video.

The methods-not-media hypothesis (Clark, 2001) claims that “there is no evidence for a causal connection between media and learning.” Clark also claims that “there is no credible evidence of learning from any medium or combination of media that cannot be explained by other nonmultimedia factors.” An interpretation stemming from this hypothesis is that while it is possible to learn effectively using multimedia, the method of instruction is also highly important in order for the media to be effective in teaching the content. This study observed the effects of two different variables on both student achievement as well as motivation to continue learning. The first variable studied was whether the medium and environment in which the media was presented made a difference to students (in both achievement and motivation to learn). The two mediums tested were a desktop computer and an iPad. The second variable studied was the effect of using a continuous playback video versus a segmented video in which the video was broken up into slides where the student would have to physically click a button to go to the next slide.

This study was conducted on 89 college students who were given class credit to participate in the study. The students were first split into two groups, one of which was given
iPads and the other desktops. These two groups were then split again with half the students in each of the original groups receiving a continuous playback video while the other half received the segmented video lesson. After the video lessons were completed, students took a post-test as well as a survey that was used to gauge the learner’s interest in continuing to learn.

The results from this study revealed that the type of medium used as well as the type of method of instruction had two different effects on the achievement and motivation to learn among the participants. When students used an iPad as opposed to a desktop computer, their answers to the survey showed that were more motivated to continue learning. However, when comparing the results on the post-test, there was no statistically significant difference in scores when comparing those that used the iPad compared to the desktop computer. On the other hand, the results were reversed when comparing students that received the continuous lesson as opposed to the segmented lesson. The students that watched the lesson continuously had lower scores on the post-test, yet their motivation to learn was unchanged. According to the authors, these results support Clark’s method-not-media hypothesis in that the medium by which the media is delivered is much less relevant compared to the method used to portray that media. Achievement, in this study, was shown to be unaffected by medium and much more affected by the method in how the content was presented. By providing a segmented video lesson where students are able to stop, think, and absorb the information before moving onto the next segment is highly effective in developing student understanding. In environments such as flipped classrooms, this particular finding should be noted because simply assigning a video for students to watch and expecting them to learn from it simply doesn’t work unless they are encouraged to do some interacting with the content. I think this is where the software developed by Edpuzzle is so beneficial for teachers to use because there isn’t a need to create an entirely new library of
content. The software allows teachers to import any video from the internet, whether they created it themselves or are using a video from Khan Academy, and input checkpoints where students are able to check for understanding by answering a question on a short segment of video that they just watched. The software also features the ability for students to replay certain parts of the video if they aren’t sure of the answer to the question. Furthermore, Edpuzzle can be used on both desktops and on mobile devices so the students are able to choose whichever device they feel more motivated to learn with.

According to the multimedia teaching theory (Mayer, 2005), learning is enhanced when words and pictures are used together. This is based on ideas of duel coding, limited capacity, and active processing. Several studies done previously with older adolescents have shown that teaching students through multimedia is more effective than traditional methods. This study was done to determine the effect of multimedia learning on achievement and attitude towards learning science with a group of relatively younger students. The study followed a pre-test and post-test model with a control group and an experimental group. The control group was taught a unit on food and healthy nutrition using traditional methods whereas the experimental group was taught using software developed by the researcher which utilized an animated web-based learning method. The students in the experimental group were taught in a computer laboratory under the guidance of their teacher.

Implementation of intervention lasted eight weeks including the pre-test and post-test. In total, two groups of 31 students selected randomly participated in the research. Student academic achievement was measured through the pre-test and post-test scores and their attitudes towards learning science were obtained using the “Science and Technology Attitude Scale” which is a Likert type survey containing 20 items.
Findings from the post-test analysis show that students who learned via the experimental method had statistically significant higher scores compared to the students taught using traditional methods, when controlling for the slight differences in initial pre-test scores. The results from the “Science and Technology Attitude Scale” show that students in the experimental group had a medium increase in their attitude towards learning which was still statistically significant. Additionally, it was found that teaching students via multimedia methods was especially beneficial for young girls. Unfortunately, girls are highly underrepresented in most STEM based fields in today’s society and are often uninterested in pursuing it as a career choice. This research hints to us that using educational multimedia to supplement classroom practices can possibly have a positive effect on the learning girls and boys alike and decrease the gap in representation in girls in STEM fields within higher education.
Chapter III – Applications

The effectiveness of the flipped classroom and other techniques that utilize technology and digital video as their primary means of education have proven themselves valid within the literature (Mayer, 2009; Sezer, 2017; Olakanmi, 2019). However, the goal of this project is to improve upon the standard video learning model in which students are simply consuming media by transitioning into a student-centered model where they are required to interact with the media in order to progress with the lesson. This transition is designed to improve the overall effectiveness of the video learning process and promote higher level learning among students involved in a “flipped” learning environment. This chapter will include exemplary videos made by professional educational content creators on YouTube. The videos will then be uploaded to Edpuzzle where they can be cropped and modified to include strategically placed stopping points for students to be assessed on their understanding of the video content. Each video, along with the included questions, will be aligned with a learning standard from the Next Generation Science Standards (NGSS Lead States, 2013). Completed Edpuzzle lessons can be found via the links embedded below. For the purposes of this project, screenshots of video stopping points will be included as well to give a sense of the video’s specific topic. The aligned Next Generation Science Standard is also included after the title of the video lesson.
Application #1 – Is it better to be a fisher or a pirate?

(MS.LS2.A) – Interdependent relationships in ecosystems – Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. In an ecosystem organisms and populations with similar requirements for food, water, oxygen, or other resources, access to which consequently constraints their growth and reproduction (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd06462dd6e7a406f2cbedb

**Figure 1.** In this video produced by the YouTube channel Veritasium, the topic of competition is discussed using seagulls as an example. At around three minutes, the video is at an appropriate length that will easily keep students focused the entire time. The animations are engaging and the video is not overly simplified and refutes the misconception that there is a correct answer to the question originally proposed by the video.
Application #2 – Why do some species thrive in cities?

(MS.LS4.C) – Adaptation – Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd061f5b1df60406936d924

**Figure 2.** This video produced by the MinuteEarth YouTube channel starts of with a question that is relevant to many students because most of them should be familiar with animals that they can find around their town such as raccoons, mice, etc. The question, “why do some species thrive in cities?” is one that many students might not have ever asked or pondered previously. For this reason, it should remain engaging as they learn not only the answer to the question, but also how adaptations are influenced by the environment in which organisms live in. The length of this video is appropriate for its audience and the content is not an overly simplified explanation, making this video exceptional in terms of meeting the criteria of a well-made educational video.
Why are only certain individuals able to survive in urban environments when others cannot? Use examples from the video to help explain your thoughts!
Application #3 – Why pets have surprisingly small brains?

(MS.LS4.B) – Natural Selection – In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits by genes, which are then passed on to offspring (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd061c8a2ad8540692abb5a

**Figure 3.** Most students have pets, or are at least familiar with the idea of owning one. This video discusses how selective breeding eventually decreased the size of domesticated animals’ brains. This video produced by MinuteEarth is short in length while also remaining engaging and providing a high level of detail in the explanation.
Application #4 – Why poor places are more diverse

(MS.LS2.C) – Ecosystem Dynamics, Functioning, and Resilience – Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. Biodiversity describes the variety of species found in Earth’s terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem’s biodiversity is often used as a measure of health (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd061afa2ad8540692ab654

**Figure 4.** This video uses a common misconception among many students that only places such as forests are abundant in the number of species within them. Teaching through a refutation can greatly increase student engagement and also results in a higher level of understanding.
Application #5 – Why don’t perpetual motion machines ever work?

(MS.PS3.B) – Conservation of Energy and Energy Transfer – When the motion energy of an object changes, there is inevitably some other change in energy at the same time. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd06176e616504064022e3b

Figure 5. Similar to other videos represented in this chapter, introducing students to a topic by asking an engaging question is just as important as the content of the video itself. This video can also address the misconception among middle school-aged children that it is possible for a machine to run forever. Keeping the content down to around five minutes is also a factor that can keep the attention of the students.
Application #6 – Does the Earth pull on the Moon, or does Moon pull on us?

(MS.PS2.A) – For any pair of interacting objects, the force exerted by the first object on the second object is equal to the force that the second object exerts on the first, in the opposite direction (Newton’s third law) (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bbad8409f779640c02a8502

**Figure 6.** The video here created by Veritasium is a great example of how educators should use common misconceptions to their advantage when creating educational videos. Students may believe they already know the answer to the initial question, however, it is quickly revealed that there is much more to be learned about this topic which will grab the attention of the viewer.
Application #7 – Where do our drugs come from?

(MS.LS4.D) – Biodiversity and Humans – Changes in biodiversity can influence humans’ resources such as food, energy, and medicine, as well as ecosystem services that humans rely on – for example, water purification and recycling (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bbad617bf809140ba0c229d

**Figure 7.** Another video created by MinuteEarth, this one is a good example of how simple questions that students may never think to ask can lead them to learn more about a unique topic that is also relevant to the Next Generation Science Standards.
Application #8 – Where do trees get their mass from?

(MS.LS1.C) – Organization for Matter and Energy Flow in Organisms – Plants, algae, and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bbad5e6bf809140ba0c2186

**Figure 8.** This video is a great example of combining both a simple, engaging question with refuting common misconceptions. Even after learning about photosynthesis, it is still common for students to not fully understand where the mass of a tree actually comes from. By teaching it to them while refuting their misconceptions, student engagement is captured and the concept is clarified.
Application #9 – Why does metal always feel cold?

(MS.PS3.A) – Definitions of Energy – Temperature is a measure of the average kinetic energy of particles of matter. The relationship between temperature and the total energy of a system depends on the types, states, and amounts of matter present (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bbad5c9422f2a40c681a758

Figure 9. The qualities of this video are similar to the one represented in Figure 8, in that it combines a simple question with common misconceptions.
Why does metal always feel cold? (PS3.A)

Write a conclusion:
Why is touching an object not a way to measure its temperature? Put these parts of a sentence in the correct order:
colder/ they conduct heat/ tend to feel / than they are / objects / when / well.
Application #10 – Polymers – Indestructible coating?!

(MS.PS1.B) – Chemical Reactions – Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants (NGSS Lead States, 2013).

https://edpuzzle.com/media/5bd06137a2ad8540692aaae3

Figure 10. Finally, this video captures the attention of the viewers early on and utilizes that engagement to teach students the basics behind chemical reactions and polymers. The length is appropriate and explanations of how polymers work are not overly simplified, requiring higher level thinking by the students that view and interact with the Edpuzzle.
Chapter IV – Reflective Discussion

With the production of digital media content rising exponentially, the video collection of teachers using a flipped classroom model is becoming increasingly saturated with educational content. While a larger number of choices is almost always beneficial to the user, this also complicates issues due to the fact that much of the content being released is not ideal for classroom use. The aim of this project was two-fold – to establish criteria which identify educational multimedia that are particularly effective for teaching science and to use Edpuzzle software to create examples of how multimedia learning can be transitioned from a technology-centered approach to a learner-centered approach. There are several criteria discussed in recent literature that outline what constitutes media that is appropriate for video learning through methods such as the flipped classroom. These criteria have included optimal length of the video being approximately five minutes as opposed to the previously thought ten minutes (Slemmons, 2018), addressing misconceptions as opposed to overly simplified explanations (Muller, 2008), and including engaging content that is relevant to the audience (Muller, 2008). When digital media engage their viewers and grab their attention early on, it becomes much easier to teach them about certain topics. This is especially true for younger students. Incorporating interactivity into online educational media is imperative to ensure that students are focused on the content and not on something else that could be distracting them. The primary concern among teachers inquiring the use of the flipped classroom is that the students will either not watch the provided videos or not pay attention to them. When using Edpuzzle to modify content and assess students while they are engaged with the video, teachers have little to worry about when they can be confident that students will be focused and assessed while interacting with the appropriate educational media.
The transition from a technology-centered approach to a learner-centered one in terms of multimedia learning is defined as shifting the focus from students watching videos and being obligated to absorb information to a model where students are interacting with the media in a way that promotes a much deeper understanding. Without the interactivity piece embedded into the multimedia, learning through video does not become better than traditional lecture, it simply becomes an alternative. With the rise of the more modern style flipped classroom, all pieces should become improved, not just the in-class portion. Improving the typical classroom environment should involve improving every facet of it, including the way information is transmitted to the students.

Of course, utilizing these criteria described to identify appropriate videos for learning should not be limited to just flipped classrooms. Traditional classrooms can use interactive video learning as well as a supplemental strategy for learning. Students can use these interactive media in a typical classroom to relearn old topics or solidify their understanding through multiple perspectives. The subject of science covers a range of topics almost as diverse as the students that study it. No two students will learn at the same pace and for this reason, giving students the opportunity to do so by providing several means of exposure such as interactive media can only benefit the students. No single method of teaching is meant to be the sole way which students learn and interactive multimedia is not uniquely excluded from this. That being said, teachers should always strive to use interactive forms of learning in place of passive ones and the addition of interactivity in multimedia learning can very likely be the key to transforming the way students learn in the classrooms of tomorrow.
References


